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EVALUATION OF AN ENERGY ABSORBING CREW SEAT INTEGRATED WITH A ROCKET EXTRACTION SYSTEM

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ABSTRACT

Consideration has been given to equipping the scaled prototype shuttle vehicle with a lightweight energy absorbing seat integrated with a crew extraction rocket. Such a system would provide protection for low velocity vehicle impacts and also offer a means of escape during higher velocity conditions. This system has been developed and fabricated at the Flight Research Center (FRC). The energy absorbing seat has been tested in a dynamic impact laboratory with satisfactory results. The escape system has been evaluated by extracting dummies by tractor rockets from a typical cockpit configuration. These tests indicate unsatisfactory performance during high roll rates.

INTRODUCTION

The NASA FRC is presently in the design stage for a one-third scale prototype shuttle vehicle based on the delta wing concept which is intended for launch from a B-52 aircraft. The Center is pursuing several technological development areas to facilitate this design stage. In the biotechnology area, flight experiments to establish minimum but adequate visibility envelopes are being conducted. Also, investigations of crew thermal and pressure protection systems and crash and escape systems are being conducted. In this latter area two different concepts were selected as candidates for consideration; an ejection seat and an energy absorbing seat integrated with extraction tractor rocket. Performance characteristics of ejection seats are understood to the point that further experimental work was not considered necessary to evaluate the application of these seats to the scaled prototype shuttle. In the event this candidate is selected, consideration is being given to the F-106 ejection seat as modified for use in the XT-2 Japanese Fighter and specifications for this seat are available from the FRC.

However, experience was lacking in the use of a flight-qualified crew seat capable of absorbing energy and integrated with a tractor rocket to extract the crew member during an emergency. Certain physical characteristics of this type system, such as being lightweight and simple in design, were considered attractive enough to warrant an experimental investigation of actual performance characteristics.

This paper briefly discusses the FRC's experience related to the design, fabrication and testing of an energy absorbing seat integrated with an extraction tractor rocket.

GENERAL DISCUSSION

Experience pertinent to energy absorbing design and testing techniques was obtained through the design and fabrication of a dynamic impact laboratory (ref. 1) and the fabrication and testing of an energy absorbing seat for use with the Flex wing vehicle (ref. 2) previously flown at the FRC.

Evaluation of a lifting body crash led to an energy absorbing seat design that lowered the pilot to a position where his head is below the structural level of the fuselage and would, consequently, provide an added measure of protection to the head.

This film clip (1)* shows a lifting body crash landing. The vehicle exhibits a high roll rate in excess of 200 degrees per second during the crash sequence. The pilot miraculously lived through this crash and the worst bodily damage was to the head; he has permanently lost the use of one eye.

Consequently, the seat shown in Figure 1 was designed to lower the pilot's head to within the top fuselage level while simultaneously absorbing energy by the use of a cyclic strain attenuator (CSA). The CSA used has a total stroke distance of 11 inches and is designed to start lowering the pilot and absorbing energy at approximately 10 g's, depending on the pilot's weight.

Several dynamic impact tests were made to verify design:

This first film (2) shows a 25-foot per second impact with a high vertical component. This design satisfactorily absorbed energy but did not lower the head to the desired height. The seat was repositioned within the fuselage frame allowing for an adequate outside viewing envelope and impacted again at the same test conditions illustrated by this second test sequence. This design was considered adequate for lowering the pilot to a height sufficient to provide improved head protection.

Figure 2 illustrates where three-axis accelerometers were used during the impact testing. As may be seen, there is a three-axis accelerometer located in the head, the pelvic region, the seat, and directly below the seat on the fuselage frame. The data to be discussed shall only include vector accelerometer readings from the pelvic region and from the vehicle frame which best illustrate the energy absorption characteristics of this total system.

Figure 3 shows acceleration versus time as measured at the vehicle frame and within the pelvic region of the dummy. The impact velocity for this test is approximately 25 feet per second with vehicle frame peak g readings of approximately 86 g's and a peak pelvic reading of 30 g's.

*See reference 3 for details on obtaining film.

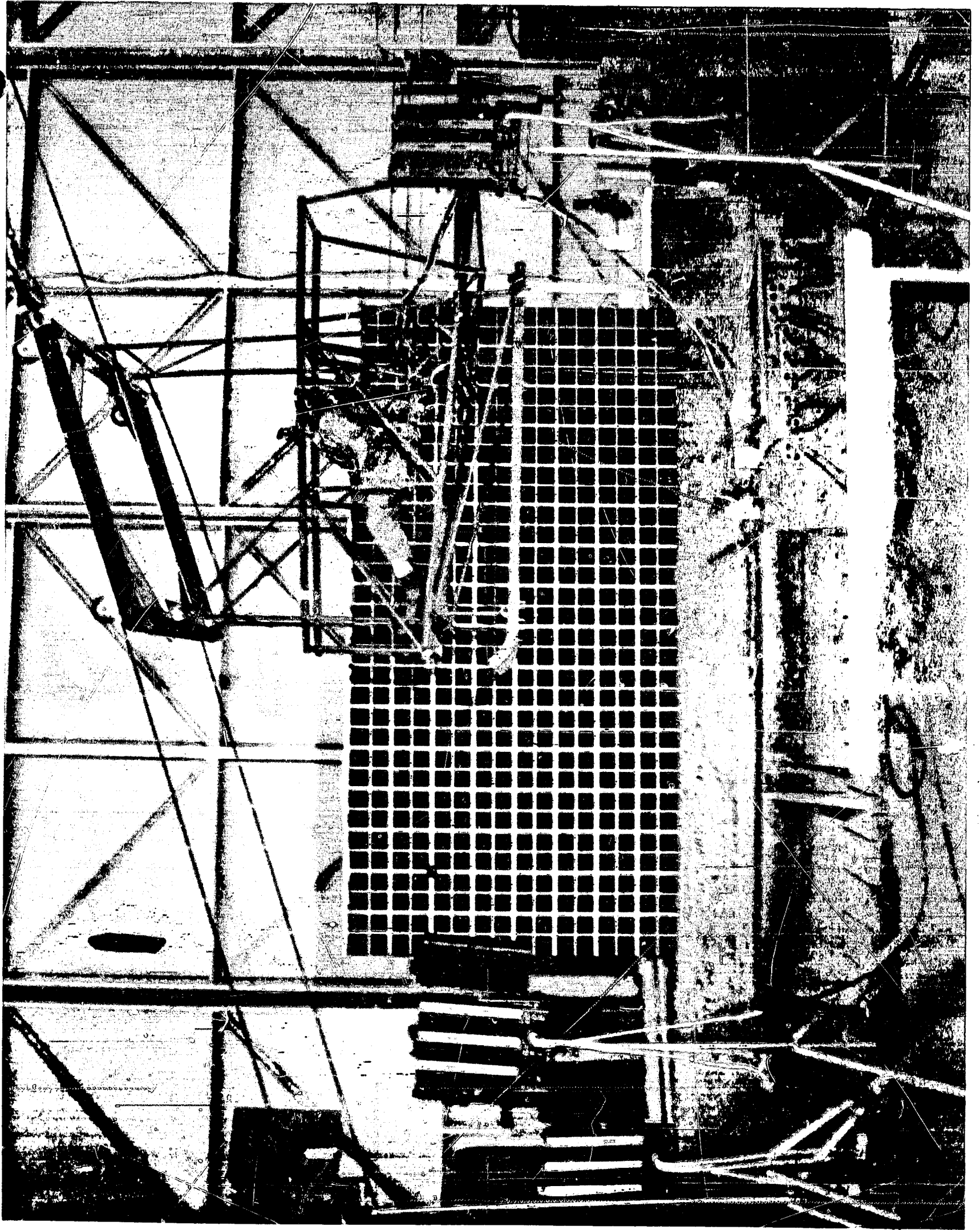


Figure 1

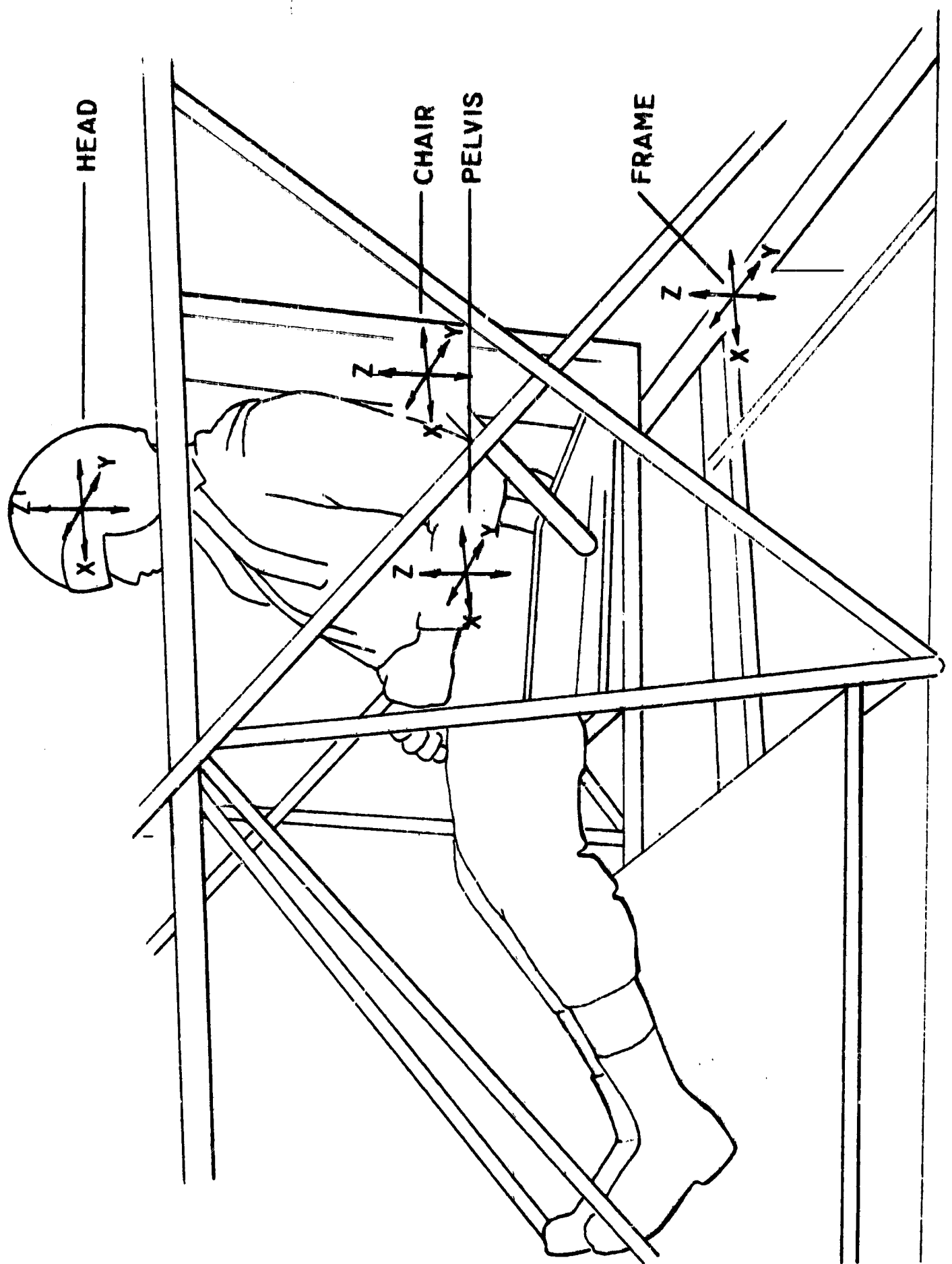


FIGURE 2
TYPICAL ACCELEROMETER ARRANGEMENT

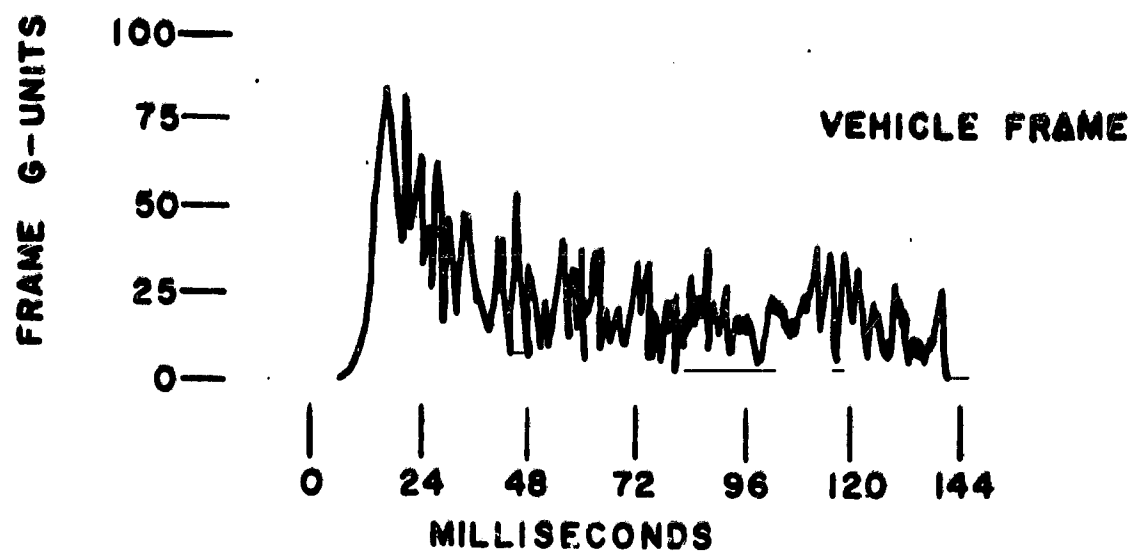
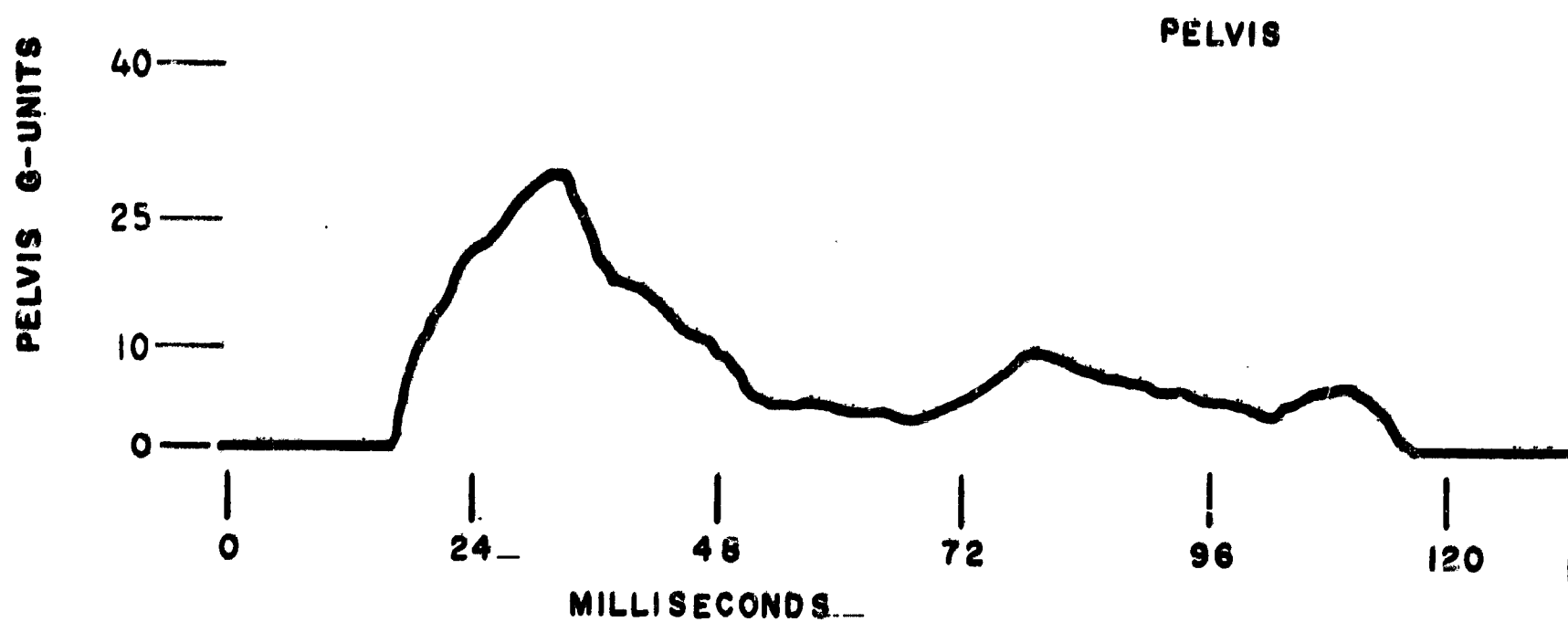


FIGURE 3
SHUTTLE SEAT IMPACT TEST
ACCELERATION VECTOR SUM MAGNITUDE
FOR THE VEHICLE FRAME AND PELVIS

However, the energy absorption characteristics of the CSA are better shown by transforming these data into the frequency domain. Figure 4 illustrates the relative difference of the spectral amplitude in g-seconds between the frame and pelvic acceleration levels as a function of frequency. Note that the high energy levels are in the low frequencies for both the frame and pelvis, where for the frame near the DC level the energy level peaks are about 2.25 g-seconds and the pelvis peaks at 0.8 g-seconds; as indicated, the energy level for the pelvis readings has decreased by a factor of three.

Figure 5 shows the gain factor which is the ratio of the amplitude in g-seconds of the pelvis to the frame. That is, for values less than zero, the pelvis experiences less transfer of energy through the frequency range until 75 hertz, at which time the values fluctuate around zero.

But as may be seen from Figure 4, there is essentially no energy in the system above 75 hertz. These data indicated that the energy absorbing characteristics of this seat were adequate for the available stroke range of 11 inches. At the conclusion of the impact testing, the program moved into its second phase which involved integrating this seat with a tractor rocket system capable of extracting a crew member during an emergency.

Figure 6 shows a tractor rocket mounted on its launcher attached to the back of the seat. During an emergency the pilot pulls a single handle between his legs which blows away the canopy and pneumatically launches the rocket which is attached by a 10-foot line to the pilot harness. When the rocket reaches the end of the 10-foot line, the rocket is ignited and pulls the pilot from the vehicle with a 1,000 pound-second impulse. During the sequence, the seat pan drops and the seat slides up rails to guide the pilot from the vehicle during the extraction.

This high-speed photography film clip (3) illustrates a successful extraction at 0/0 conditions when the vehicle is in a stable configuration. However, as mentioned, experience at the FRC with research vehicles such as the X-15 and lifting bodies during emergencies has demonstrated that high roll rates are probable.

This film clip (4) is an example of a rapid buildup of rates to values in excess of 270 degrees per second. This is a mockup of an actual X-15 emergency reconstructed from telemetry data. In this case, the vehicle and pilot were lost, but as may be noted from the control movements, the pilot attempts to control the aircraft until the last instant when high spin rates in excess of 270 degrees per second are reached in approximately 400 milliseconds.

It is our firm belief that a crew emergency egress system must be capable of operating at high roll or spin rates; consequently, a series of performance tests were accomplished to evaluate the performance characteristics of the extraction rocket under simulated roll rate conditions.

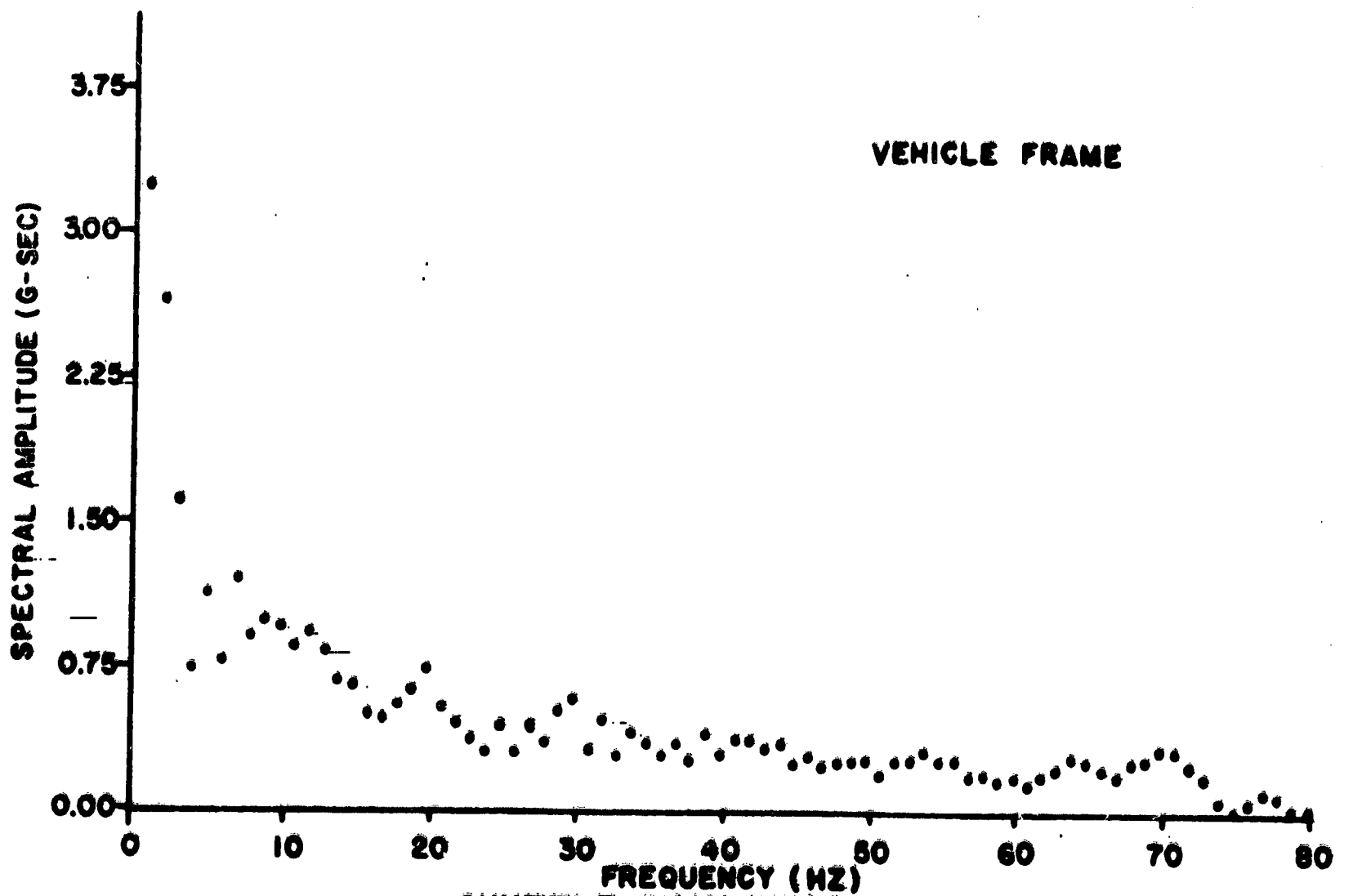
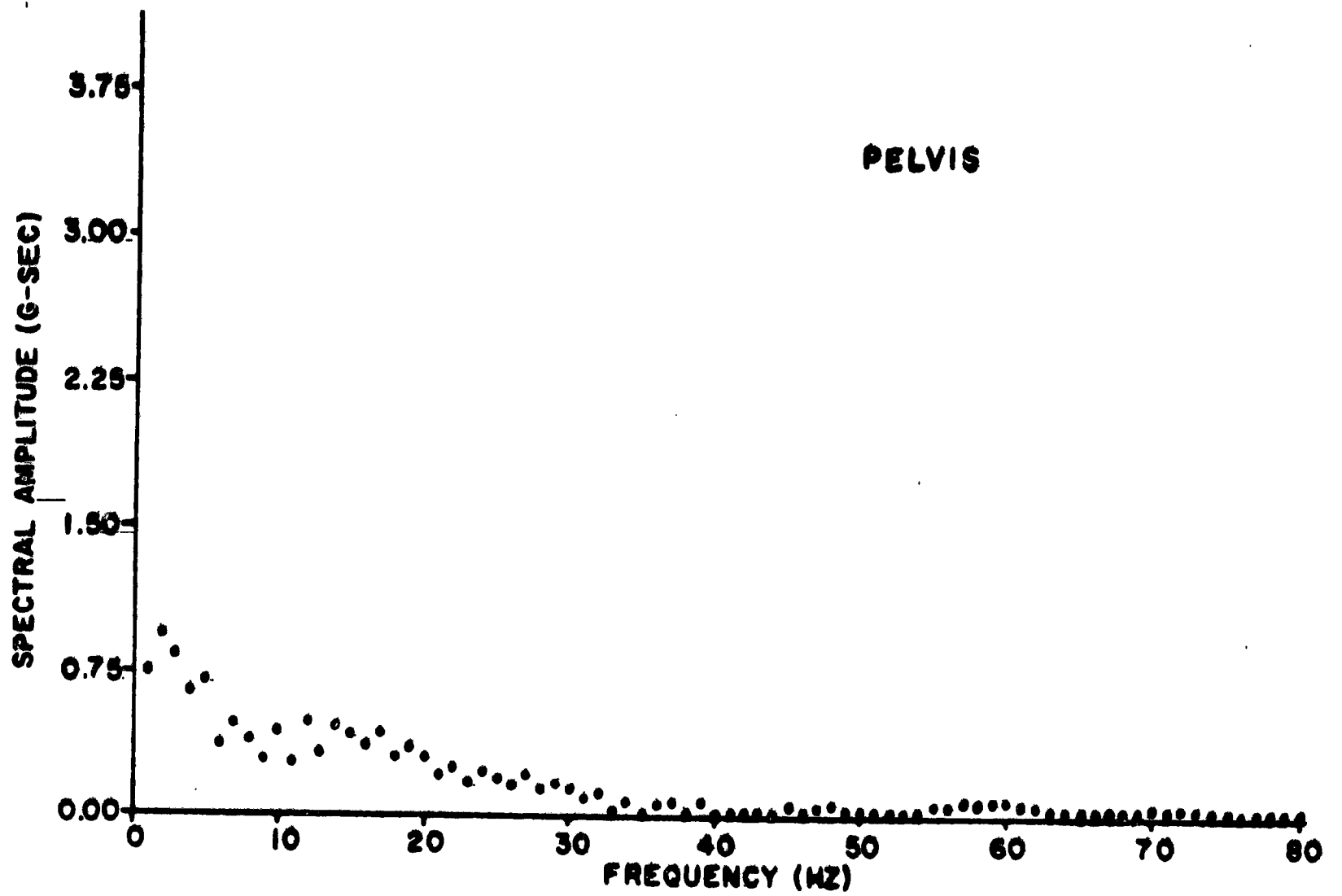
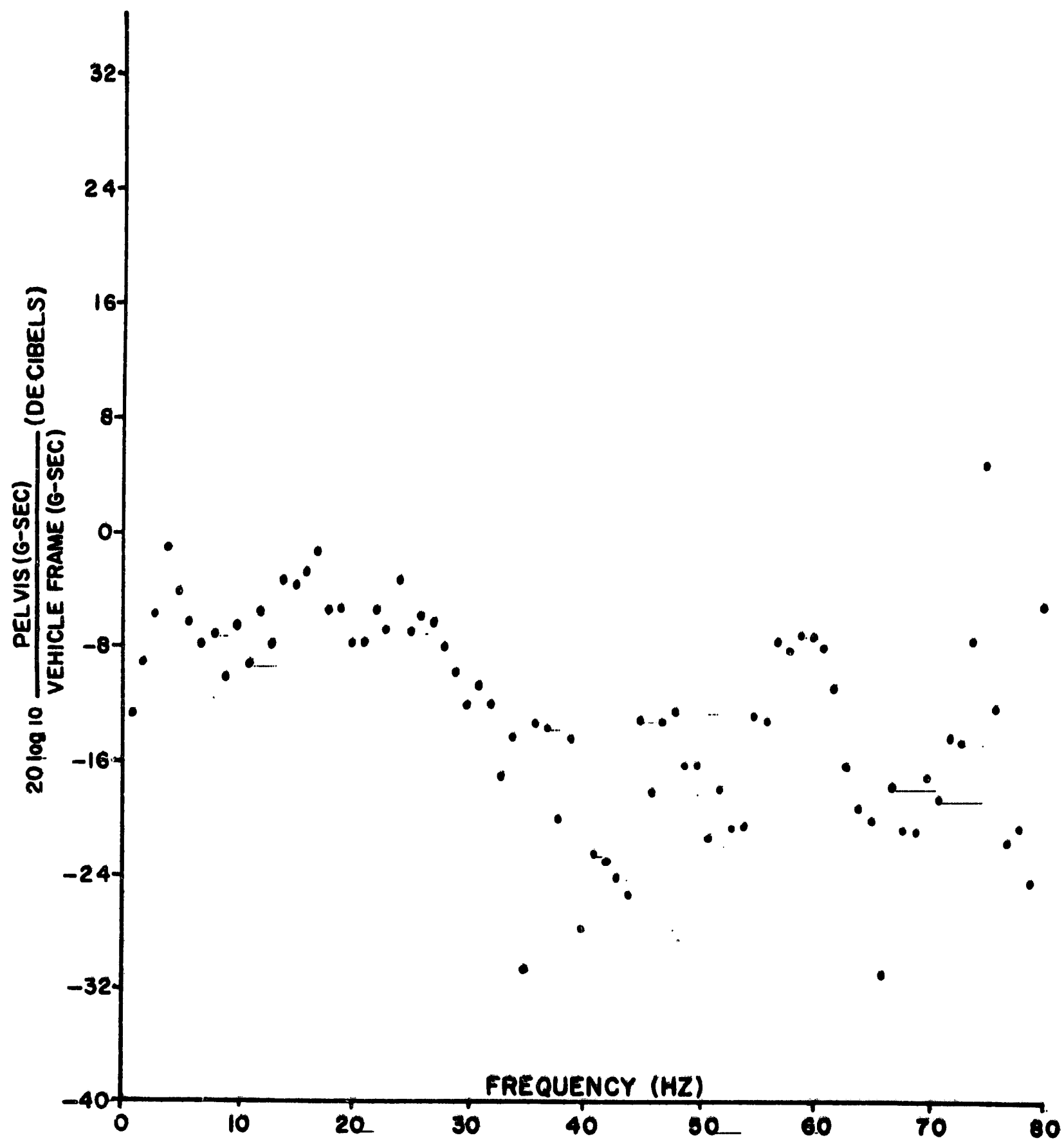


FIGURE 4

SHUTTLE SEAT IMPACT TEST
AMPLITUDE SPECTRUM VS FREQUENCY



SHUTTLE SEAT IMPACT TEST
GAIN BETWEEN PELVIS AND FRAME

FIGURE 5

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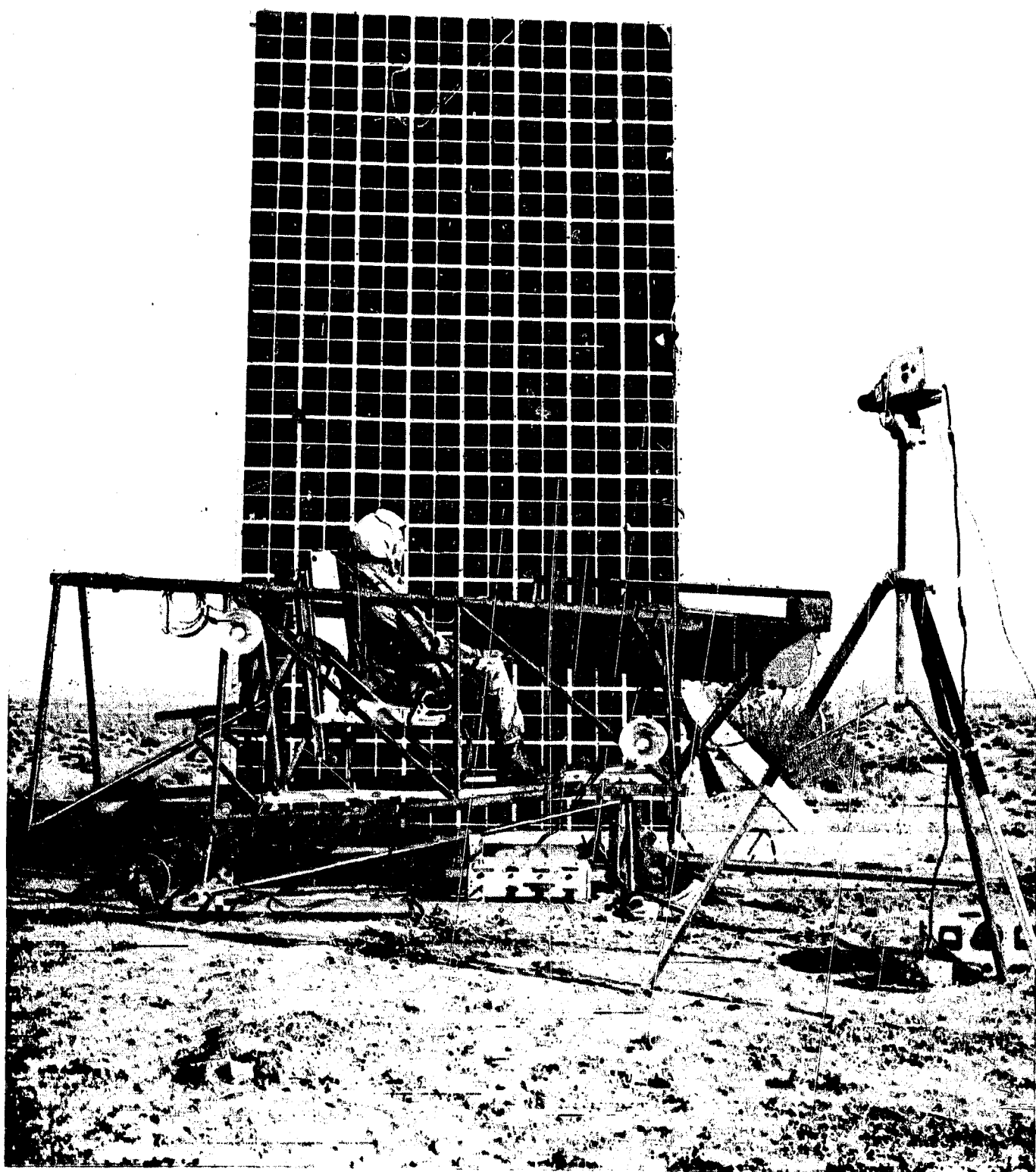


Figure 6
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Figure 7 illustrates the technique used to statically simulate a roll condition. The thrust vector of the rocket was displaced laterally from zero degrees in increments to 45 degrees.

The theoretical graph shown in Figure 8 shows corresponding aircraft roll rates as a function of rocket tilt or lateral displacement in degrees. Three firings were performed corresponding to a 60-degree per second, 80-degree per second, and 125-degree per second roll rate.

This high-speed photography clip (5) illustrates the conditions of extraction at these various roll rates:

At 60 degrees per-second the dummy was extracted without any problem.

At 80 degrees per second the dummy was slammed hard against the right side of the cockpit and dented the side of the fuselage.

At 125 degrees per second the dummy was again slammed hard against the frame. The accelerometers mounted in the thorax indicated a side acceleration of 80 g's sustained for 15 milliseconds.

Figure 8 shows the theoretical estimate of aircraft roll rate versus rocket tilt angle and our three test points corresponding to roll rates of 60 degrees per second, 80 degrees per second, and 125 degrees per second together with the time required for the various events to occur.

Two events are plotted. The top function indicates the roll rates achievable by the tractor rocket if the feet clear the cockpit. The second function provides the roll rates possible if only the torso is considered necessary to clear the cockpit.

However, our experimental tests indicated another factor, shown in Figure 9, by plotting egress time versus rocket tilt angle. Due to the additional horizontal force component caused by the dummy pressing against the side of the cockpit, the egress time increased for increasing roll rates. As indicated, from a stable 0/0 condition to a roll rate of 60 degrees per second the egress time increased 23 milliseconds and from the stable condition to an 80-degree per second roll rate the egress time increases to 54 milliseconds. For 125 degrees per second, the delay time involved in leaving the cockpit is 66 milliseconds.

When these experimental data are plotted together with the theoretical estimate (Figure 10), it is evident that the actual roll rates within which this system can operate in this cockpit are reduced. A 73-degree rocket tilt angle corresponding to a roll rate of approximately 200 degrees per second is the theoretical maximum above which a tractor rocket cannot extract a pilot. Extrapolation of actual experimental data indicates that actual possible roll rates for a tractor rocket extraction from this type cockpit are definitely less than 200 degrees per second and probably nearer 160 degrees per second, and this is not considered adequate for flight vehicles

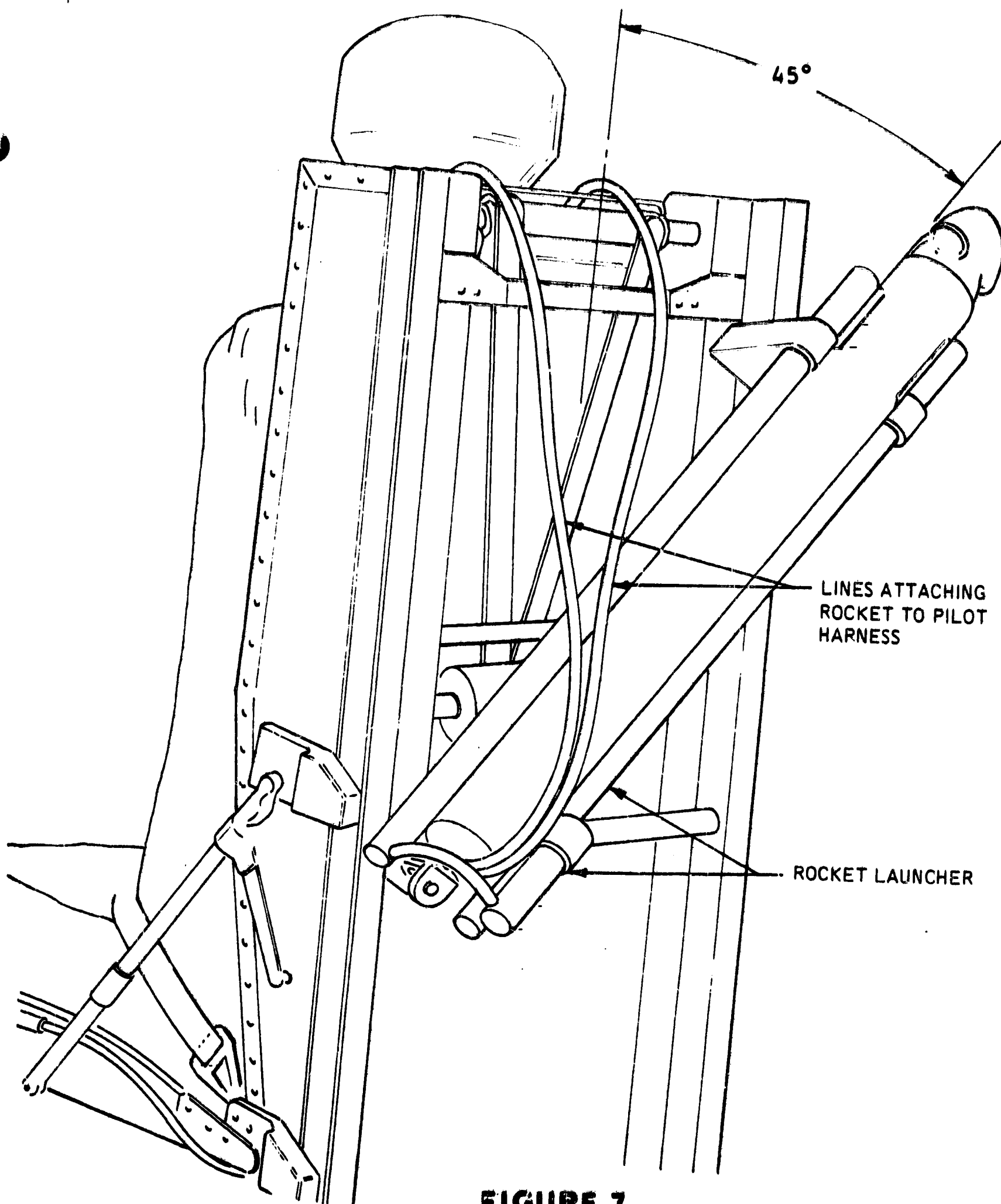


FIGURE 7
SEAT BACK VIEW SHOWING LATERAL
DISPLACEMENT OF THE ROCKET THRUST VECTOR

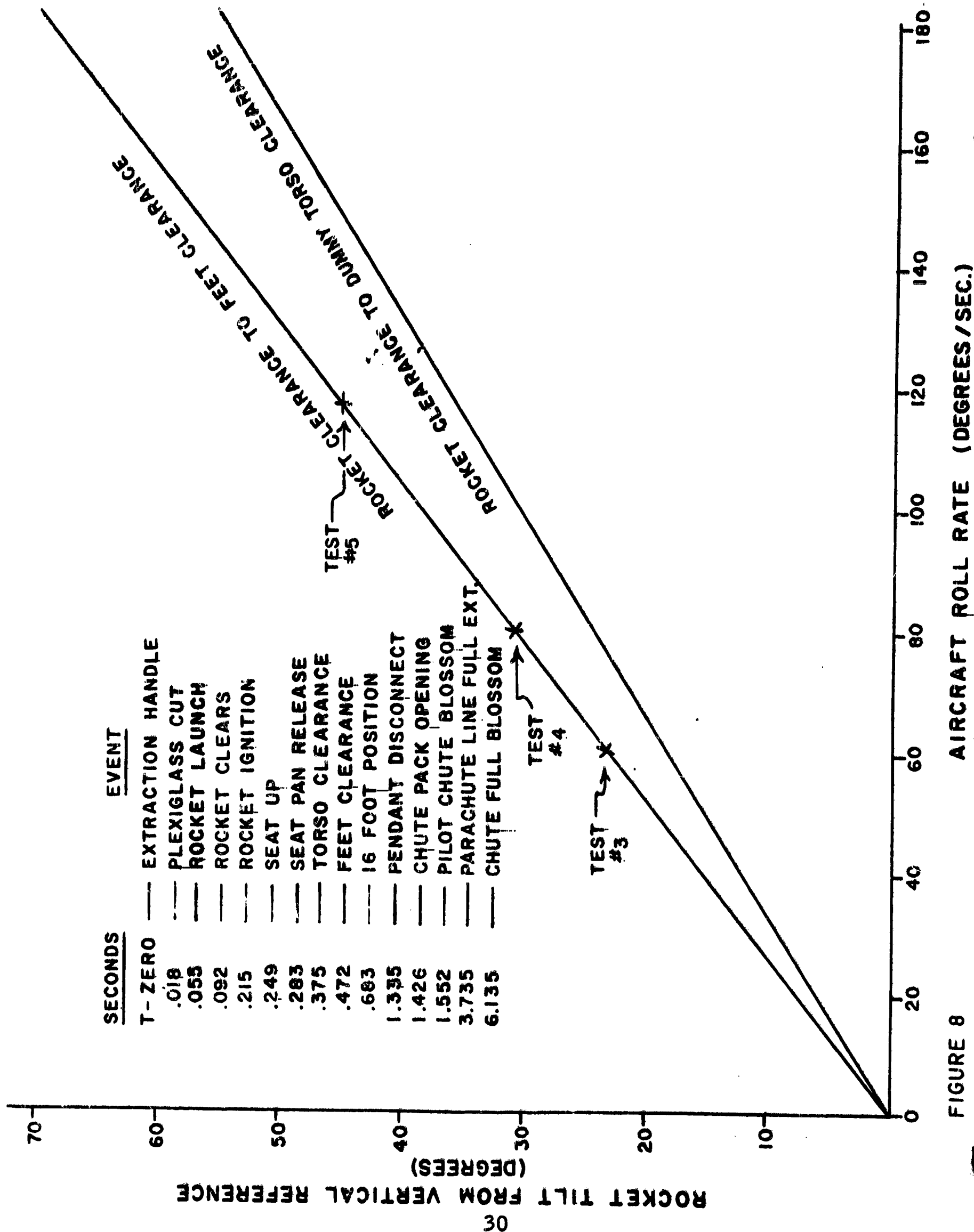


FIGURE 8

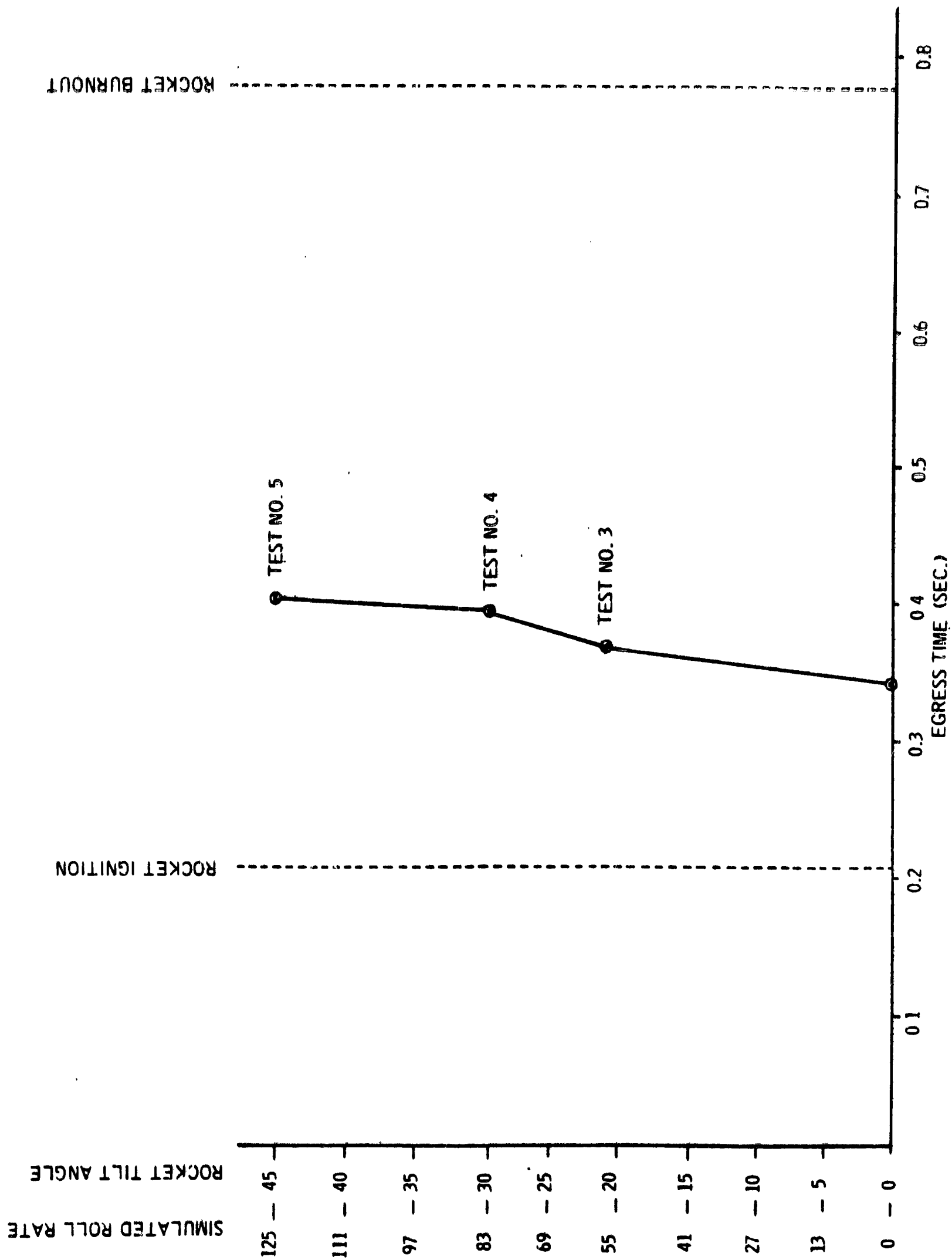


FIGURE 9

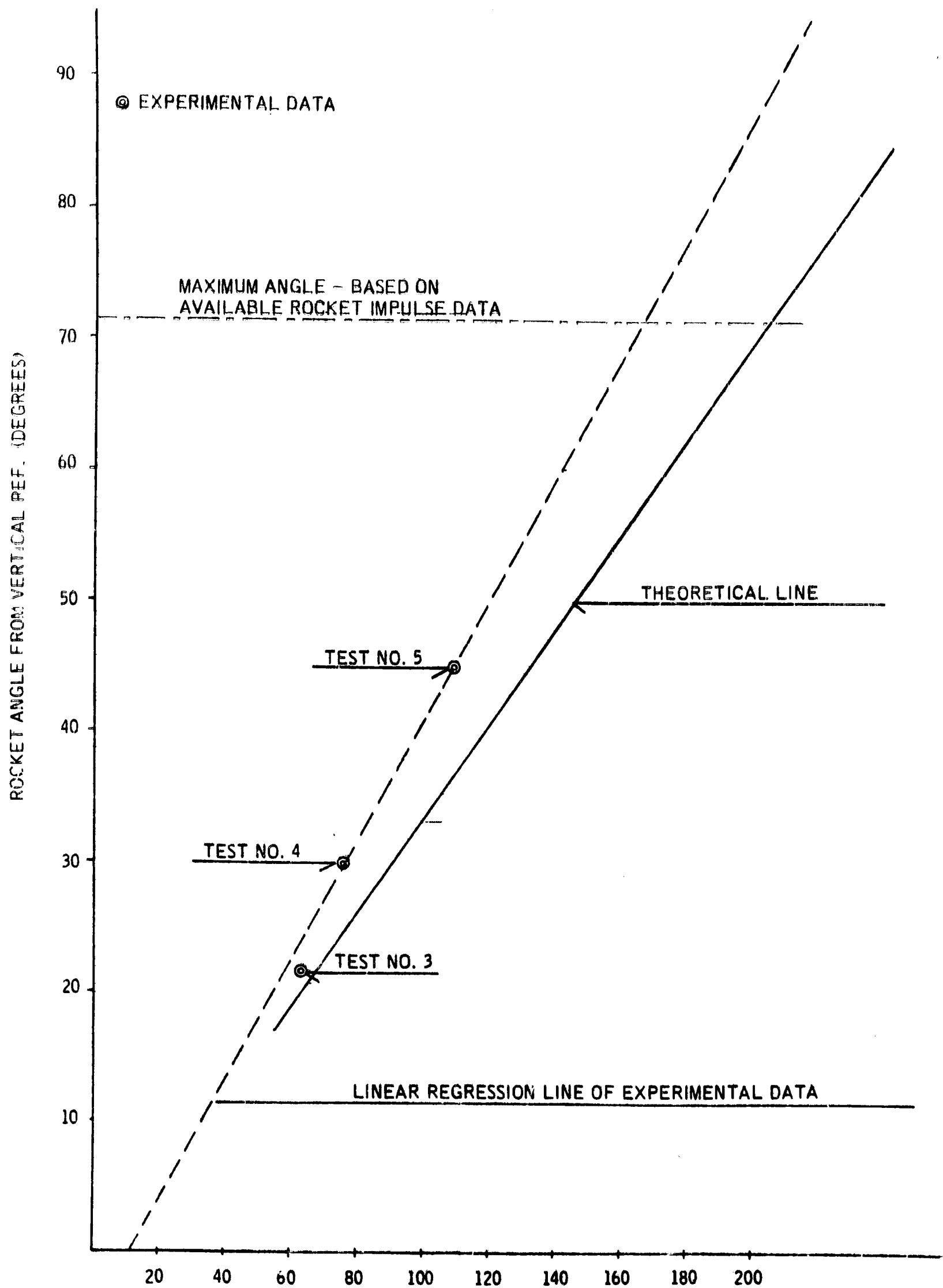


Figure 10. SIMULATED ROLL RATE (DEGREES/SEC.)

that are aerodynamically unstable in roll or capable of high roll rates particularly in view of the high side forces exerted against the dummy as he left the cockpit. These side forces seem to become significant at a simulated roll rate of 80 degrees per second.

CONCLUSIONS

1. Nonejection seat designs allowing improved head protection by lowering the pilot are now within the state-of-the-art...
2. By integrating energy absorbing techniques into the seat lowering mechanism, a significant amount of impact energy can be prevented from reaching the pilot.
3. The energy absorbing seat can be integrated with a crew extraction rocket and will perform reliably at a stable O/O condition and at relatively low roll rates.
4. The tractor rocket egress system is not recommended for use with flight vehicles where high roll rates can be expected.
5. This type seat and egress system is not recommended for use on the scaled prototype shuttle vehicles where roll rates in excess of 200 degrees per second can be anticipated.
6. The recommendation now being considered for the crew egress system for the scaled prototype shuttle is to use the F-106 ejection seat as modified for the XT-2 Japanese Fighter.

REFERENCES

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2. Carpenter, Richard: "Description of an Energy Absorbing Seat Designed for Medium-Velocity Impacts." Presented at the Annual NASA Safety and Risk Management Conference, Lewis Research Center, September 30-October 1, 1970.
3. "Film for the Joint AIAA Space Shuttle Development Testing and Operations Conference/NASA Shuttle Technology Conference, March 15-18, 1971, in Phoenix, Arizona." May be obtained from National Aeronautics and Space Administration, Flight Research Center, P. O. Box 273, Edwards, California 93523, Attn: Biomedical Programs Division.